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ABSTRACT

The literature on women in science and engineering is extensive and addresses such issues as early education, decision to study and pursue careers in science, and how women fair in their jobs. This review used the literature on the careers of women scientists and engineers employed in academia to examine how women in these disciplines fare compared with their male counterparts. The women represented in this review have mostly completed their formal educations and have made the decision to pursue academic careers in science and engineering. Taken as a whole, the body of literature reviewed provides evidence that women in academic careers are disadvantaged compared with men in similar careers. Women faculty earn less, are promoted less frequently to senior academic ranks, and publish less frequently than their male counterparts. (Author/MVL)

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Gender Differences in the Careers of Academic Scientists and Engineers: A Literature Review

Special Report

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National Science Foundation

June 2003

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Gender Differences in the Careers of Academic Scientists and Engineers: A Literature Review

Special Report

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Section 1. Introduction

The literature on women in science and engineering is extensive and deals with such issues as early education, decisions to study and pursue careers in science, and how women fare in their jobs.

This review used the literature on the careers of women scientists and engineers employed in academia to examine how women in these disciplines fare compared with their male counterparts. The women represented in this review have mostly completed their formal educations and have made the decision to pursue academic careers in science and engineering.

Summary of Findings

Taken as a whole, the body of literature we reviewed provides evidence that women in academic careers are disadvantaged compared with men in similar careers. Women faculty earn less, are promoted less frequently to senior academic ranks, and publish less frequently than their male counterparts.

Earnings

The literature on the gender earnings gap in academia is extensive. Most of the studies we reviewed show that women faculty earn less than their male counterparts do, even after controlling for other factors that affect earnings. The gender gap in earnings narrowed by the late 1970s, and several authors hypothesize that this was the result of affirmative action policies implemented in the early 1970s.

The estimated size of the earnings gap appears to be sensitive to the kinds of control variables used in various studies. Studies that control for academic rank, publications, and family characteristics tend to show smaller earnings gaps than those that do not. However, evidence on the direct and indirect effects of marital status and parental variables on the earnings gap is mixed.

Academic Rank

There is substantial evidence that women, as a group, are underrepresented in senior academic ranks. In part, this is because women faculty tend to be younger than their male counterparts, a consequence of the relative increase in the number of women graduates entering the fields of science and engineering.[1] Many of the studies we reviewed, however, show that even after controlling for other factors affecting promotions, including experience, women are less likely to appear in senior ranks. Some studies provide evidence that women are particularly disadvantaged early in their careers, during child-rearing years.

Scholarly Productivity

Many researchers use measures of scholarly productivity as control variables in both salary and academic-rank studies. Scholarly production is typically a significant factor in determining earnings and promotions, and many authors noted that women faculty members publish less on average than their male counterparts do.[2] Thus, gender differences in publication rates explain, at least partially, differences in average earnings and promotion rates between women and men. One study, however, which used a quality-weighted index of scholarly output, found that female economists are more productive than their male counterparts are.[3] Also, some of the gender differences in productivity might be explained by job selection and gender sorting by coauthors. Men and women tend to collaborate with coauthors of the same sex. Because there are relatively few women in faculties, women are placed at a disadvantage because it is more difficult for them to find collaborators.

Organization of Report

Sections 2 through 5 of this report deal with background issues, findings on the gender earnings gap in academia, the effects of gender on tenure status and academic rank, and the literature on gender differences in scholarly productivity. Section 2, on background issues, provides a context for interpreting the findings in the literature. The last three sections of this review are connected by a common theme. Findings in the literature indicate that the gender earnings gap is at least partly due to gender differences in promotions and scholarly productivity.

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[1]See, for example, Everett et al. (1996), Carnegie Foundation (1990), and Heylin (1989). Women faculty would also be younger than men if lower tenure rates cause higher female exit rates from academia.

[2]See, for example, Cole and Singer (1991).

[3]See Koplin and Singell (1996).

Section 2. Background Issues

The background issues described in this section are important for interpreting the literature on women in academic careers. These include human capital and occupational choice theory, the kinds of data that are typically used in empirical research on the effects of gender on academic careers, and selection issues that complicate interpreting the results of empirical research.

Human Capital Theory and Occupational Choice

Human capital is the set of skills and abilities that enable individuals to perform jobs. Individuals can acquire or add to their stock of human capital through education and training. Economic theory suggests that individuals invest in education and training to realize the expected future benefits of both earnings and nonpecuniary amenities associated with employment.

Clearly, individuals with doctoral degrees have made substantial investments in human capital. These investments include the direct costs of education plus the opportunity costs of earnings forgone during schooling.

Individuals can also accumulate human capital through on-the-job experience. For example, doctorate earners might reasonably be expected to improve both their research and their teaching skills with experience, particularly during the early years of their employment. Even within academics, different jobs lead to the formation of qualitatively different human capital. For example, an individual who takes employment in an academic department that stresses research is likely to acquire skills quite different from an individual who works at a teaching institution.

One issue raised in the literature is whether women and men acquire qualitatively and quantitatively different levels of human capital because of family and parental responsibilities. One hypothesis is that human capital accumulated by female scientists and engineers depreciates when childbearing and child rearing interrupts their careers (or alternatively, that women accumulate human capital at a slower rate than men do because parental responsibilities interrupt their participation in the workforce). A second hypothesis, advanced by Johnson and Stafford (1974), argues that women have less incentive to accumulate human capital than men do because child rearing leaves them with less time to realize returns on their investments. Johnson and Stafford argued that the tendency of women to take jobs at teaching rather than research institutions reflects occupational choices that trade human capital accumulation for short-term economic benefits.[4]

Some have criticized the emphasis on human capital theory in the literature. Strober and Quester (1977), for example, discounted Johnson and Stafford's argument that women's job choices reflect deliberate decisions to forgo human capital investments in favor of short-term economic gains. Colander and Woos (1997) argued that emphasis on differences between men's and women's human capital diverts attention from demand-side discrimination against women. They argued that lower pay for women faculty allow. established academic "insiders" to capture economic rent.

Data

Data requirements generally depend on the objectives and design of a particular study. However, if the objective is to measure the effects of gender on the careers of academic scientists and engineers, some general data requirements can be identified. First, measures of career outcomes are required, for example, earnings and academic rank.

In addition to measures of outcomes, well-designed studies of gender effects require data on control variables that might be expected to affect outcomes. These include measures of productivity (e.g., number of publications) and human capital (e.g., quality of graduate program attended, years of experience).[5] Also, many of the studies we reviewed contain variables reflecting personal characteristics that might affect outcomes, including age, marital status, number of children, and race/ethnicity.

Generally, the studies we reviewed used two kinds of data—data that are national in scope and data from single academic institutions. An obvious advantage of using national data sets is the ability to generalize results of studies to the national population. However, some

[4]Johnson and Stafford argued that starting pay at less prestigious institutions that emphasize teaching is higher than at more prestigious research institutions.

[5]We might argue that career outcomes should depend strictly on productivity. However, given the difficulty of measuring productivity in academia, many studies include variables reflecting human-capital accumulation as controls.

of the single-institution data sets used in the literature contain detailed measures of control variables, especially those reflecting human capital and productivity.

Two national data sets used frequently in the literature are data collected and maintained by the National Science Foundation (NSF) and by the Carnegie Foundation for Advancement of Teaching. Salary studies by NSF (1996), Johnson and Stafford (1974), and Farber (1977) used NSF data. Also, Long (2001), Olson (1999), Kahn (1993), and Weiss and Lillard (1982) used NSF data to study the effects of gender on academic rank.

The Carnegie Foundation data include relatively detailed information on outcome measures, such as salary and academic rank, and on several control variables, including sociodemographic characteristics (gender, race, marital status, and children), employment history, time spent on teaching and research, and productivity (articles and books published). Ashraf (1996), Bellas (1993), Carnegie Foundation (1990), and Barbezat (1987, 1989b) used Carnegie Foundation data for studies on gender earnings gaps.

In addition to the data described above, some researchers used national data sets that are limited to specific fields. For example, Macfarlane and Luzzadder-Beach (1998) and Ongley et al. (1998) both used data maintained by the American Geological Institute for studies of academic rank. Several authors, including Brennan (1996), Everett et al. (1996), Heylin (1989), and Reskin (1976) used data from the American Chemical Society. Winkler et al. (1996) used data from the American Meteorological Society in a salary study.

Some authors have designed their own national databases for their studies. For example, Broder (1993) drew a sample from applications for NSF grants to study the effects of gender on the salaries and rank of academic economists, and Formby et al. (1993) conducted a national survey of economic departments for a salary study. Both the Broder and the Formby et al. data, however, are limited to a single academic field. Broder acknowledged that her sample from NSF grant applications might not be nationally representative, and the Formby et al. survey yielded only 258 responses from a sample of 469.

The National Center for Education Statistics has been conducting the National Study of Postsecondary Faculty (NSOPF) every five years since 1988. NSOPF is a nationally representative survey of faculty that contains data on career outcomes and numerous control variables, including sociodemographic characteristics, teaching and research responsibilities, and scholarly productivity. Kirshstein et al. (1997) used data from the 1993 NSOPF in their study of women and minority faculty in science and engineering.

Numerous studies in the literature used data from single academic institutions. As noted above, some of the data assembled for these studies are richly detailed. For example, Raymond et al. (1988) and Ferber et al. (1978) constructed detailed measures of relative productivity (publications and research awards) by individual academic departments for their salary studies. Katz (1973) included measures of teaching quality and service to the academic community as well as detailed measures of scholarship in his study of salary at a large public university.

Longitudinal data that track individuals over time are useful for analyzing time between promotions and salary increases. However, relatively few of the studies we reviewed used longitudinal data. Farber (1977), who used NSF data,[6] and Megdal and Ransom (1985), who used data from a single institution to study salary increases, are exceptions.

Selection Issues

Occupational choice theory states that individuals select jobs that give them the largest expected future benefits; however, the feasible set of employment opportunities from which individuals make choices is constrained. Perhaps most obviously, an individual's endowment of human capital limits available choices. For example, employment opportunities at top research universities are typically available only to the most able of those with doctoral degrees, who have demonstrated high levels of academic achievement. Discrimination can also affect job choices. Gender bias, for example, can either limit the set of job opportunities available to women or make some jobs less attractive because of lower pay or reduced promotion possibilities.[7]

There is substantial evidence in the literature that female and male scientists and engineers take academic jobs that are qualitatively different. Brennan (1996) reported that women are underrepresented at research universities, and the Carnegie Foundation (1990) found a

[6] Farber used NSF panel data from 1960 through 1966.

[7] The literature provides some evidence that perceived discrimination affects job choices. Neumark and McLennan (1995) reported evidence that women who report acts of discrimination are more likely to change jobs.

concentration of women at lower-paying institutions. Koplin and Singell (1996) and Broder (1993) reported that female economists tend to be employed in less-prestigious departments. Barbezat (1992) found that women tend to be employed in academic jobs that stress teaching over research. There is also evidence that women and men tend to select different academic fields. Olson (1999) found that women are overrepresented in biology.

Barbezat (1992) conducted a survey of the employment preferences of individuals with doctorates in economics entering the job market. She found that salary and benefits are more important to men than they are to women. Women, however, place a higher preference than men do on student quality, teaching load, collegiality and interaction within academic departments, opportunities for joint work, and female representation on the faculty. Women also prefer spending more time teaching,[8] whereas men prefer research. Barbezat found that after controlling for differences in stated job preferences, gender has no effect on actual employment placements.

We emphasize that Barbezat's findings are limited to first jobs in a single field. Moreover, preferences stated by the survey subjects may be, to some extent, rationalizations of employment opportunities. In short, whether male-female differences in employment outcomes result from differences in job preferences or from limited opportunities as a consequence of discrimination is unclear.

The evidence cited above suggests that employment outcomes for scientists and engineers in academia are not randomly distributed. More likely, they reflect the combined selection forces of human capital accumulation, job preferences, and limited opportunities. Selection has important implications for interpreting the results of empirical research on the effects of gender on employment outcomes in academic labor markets. For example, if gender differences in employment at teaching and research institutions are partly the result of discrimination, then controlling for the characteristics of the employing institution in a salary study will mask the effects of limited employment opportunities for women. Similarly, if women are underrepresented in higher academic ranks because of disparate treatment, controlling for rank in a salary study will understate the effects of gender on earnings.[9] In theory, these types of selection biases can be reduced with appropriate controls for human capital and productivity. In practice, however, empirical measures of both are imperfect and incomplete.

Perceptions of Discrimination

Several studies suggest a widespread feeling among women in academics that their gender is a roadblock to their careers. These analyses of surveys and case studies indicate that women find that their gender limits career advancement (Brennan, 1992); women feel marginalized and excluded from a significant role in their departments (MIT 1999); women in the junior faculty ranks are more frustrated than men by the publishing review process; women lack practical applications for their research, respect from colleagues, and networking in their field (Macfarlane and Luzzadder-Beach, 1998); and women face more difficulties reaching tenure because of interruptions in their careers from childbearing (Brennan, 1996).

A few studies have linked measures of job satisfaction or perceptions of discrimination to career outcomes. One kind of model examines the relations between different outcomes (tenure status or wage differentials) and overall job satisfaction. A second kind of model examines the effect of job satisfaction on the likelihood of job retention and consequently on tenure.

For example, Hagedorn (1995), using a national database of faculty members in all fields, first estimated a gender-based wage differential and then incorporated the estimates into a causal model to predict several job-related measures of satisfaction. She found that the estimated wage differential has significant effects on women's perceptions of the employing institution, stress level, global job satisfaction, and intent to remain in academia.

Neumark and McLennan (1995) used data from the national Longitudinal Survey of Young Women to test a "feedback" hypothesis,[10] an alternative to the human capital explanation of gender differences in wages. Their findings only partially support this hypothesis. They found that working women who report discrimination are subsequently more likely to change employers, to marry, and to have children. However, they also found that there is no relationship between self-reported discrimination and the subsequent accumulation of labor-

[8]Women's preferences for teaching are consistent with findings reported in Zuckerman et al. (1991).

[9]Gender discrimination in promotions would leave a pool of more qualified women in lower ranks and only the most highly qualified women in senior ranks.

[10]The feedback hypothesis is that women experience labor-market discrimination and respond with career interruptions, less investment, and lower wage growth.

market experience and that women reporting sex discrimination do not subsequently have lower wage growth.

Using 1993 data from the National Survey of Postsecondary Faculty to investigate the direct and indirect effects of gender on job satisfaction, Busenberg (1999) concluded that gender affects job satisfaction among academic scientists both directly and indirectly through mediating variables. In addition, Busenberg found that the extrinsic aspects of employment are much more significant than intrinsic aspects in predicting overall job satisfaction among scientists and that research productivity is only indirectly predicted by gender.

Section 3. Earnings

Most of the studies we reviewed show that women faculty earn less than their male counterparts do, even after controlling for other factors that affect earnings. The modeling issues discussed here, which focus on the kinds of control variables used in academic salary studies, are important for interpreting our findings from the literature, which we present below.

Modeling Issues

Most of the salary studies we reviewed used multivariate regression analysis to control for factors other than gender that might affect the earnings of academic scientists and engineers. Typically, controls were for measures of human capital, measures of productivity, personal characteristics, and academic field.

Human Capital Controls

Measures of human capital that have been used in studies of academic salaries include experience, education, academic rank, and characteristics of employing institutions.

Experience

Almost all of the salary studies we reviewed include some measure of experience as a control variable. Most often, experience is measured as years since earning the doctorate.[11] Bellas (1993) and Lindley et al. (1992) also included measures of experience before earning the doctorate. Several authors, including Ransom and Megdal (1993), Lindley et al. (1992), and Megdal and Ransom (1985), included years of service at the employing institution.[12]

Measuring experience as years elapsed since earning the doctorate (or years employed at the current institution) is an inaccurate indicator of human capital accumulation in that it does not account for workforce interruptions. This issue is important in the context of measuring male-female salary differences. Because of family and child-rearing responsibilities, we might expect women, as a group, to have more frequent and longer workforce interruptions than men do. Bellas (1993) included controls for duration of both unemployment and part-time work in her salary study. Farber (1977) included control variables reflecting changes in jobs and changes in work activity.

Education

Several salary studies we reviewed contain variables reflecting human capital investments in education. Some authors used data that include faculty without doctoral degrees. These studies generally contain variables reflecting the highest degree earned (e.g., doctorate or master's degree) by faculty in the sample. A few studies—Formby et al. (1993), Johnson and Stafford (1974), and Katz (1973)—included indicators of the quality of the graduate school from which faculty earned their degrees.

Academic Rank

Academic rank was used as a control in many of the studies we reviewed. Arguably, individuals who have accumulated the most human capital are more likely to be promoted to higher academic ranks. If this is the case, academic rank can be viewed as a proxy for human capital accumulation that is otherwise unmeasured.[13]

Again, we caution that including academic rank as a control in studies of male-female salary differences is controversial. If women faculty suffer discrimination in earnings, the same might be true for promotions, and thus academic rank would systematically understate the amount of human capital accumulated by women.[14]

Characteristics of Employing Institution

Several studies control for the characteristics of the institutions at which faculty are employed. For example, Broder (1993) controlled for the quality of the employing department in her study of salaries earned by academic economists; Ashraf (1996) included the Carnegie classification of the employing institution as a control; and Bellas (1993) and Formby et al. (1993) included a variable that distinguishes public and private institutions.

Including the characteristics of employing institutions as controls in salary studies raises complicated issues.

[11] Many studies specify experience variables in a nonlinear fashion (e.g., as a quadratic) to capture potential diminishing returns to experience.

[12] Human capital theory distinguishes between general and firm-specific human capital. The notion is that each firm (academic institution) has, to some degree, unique human capital requirements. If firm-specific experience is important, we would expect firm-specific experience to have a larger effect on salary than general experience does.

[13] We could also argue that academic rank is a proxy for unmeasured productivity. The most productive faculty are more likely to be promoted to senior ranks.

[14] The same downward bias exists if we interpret academic rank as a proxy for productivity.

One might argue that the characteristics of the employer serve as proxies for human capital (i.e., individuals who have accumulated the most capital are more likely to land jobs at the most prestigious institutions), but if women are discriminated against in the academic labor market, then employer characteristics might be a biased measure of human capital.

Alternatively, one might argue that institutional characteristics serve as proxies for nonpecuniary job amenities (e.g., quality of students and emphasis on teaching rather than on research). If they do, then measures of institutional characteristics might be appropriate controls for individuals' willingness to trade earnings for nonpecuniary job amenities.[15]

The effect of employer characteristics on earnings is unclear, particularly for junior faculty. The most highly qualified individuals might be expected to find jobs at the most prestigious institutions and be compensated accordingly. But junior faculty taking jobs at the most prestigious universities might expect to accumulate more human capital than they would at other institutions. This suggests they might be willing to trade current income for future returns to investments in human capital.[16]

Measures of Productivity

The most commonly used controls for productivity are those measuring scholarship, teaching, and service to the academic community.

Scholarly Productivity

Simple counts of articles and/or books published were the most frequently used measures of scholarly production in the salary studies we reviewed. Two studies, Raymond et al. (1988) and Farber (1977), included research grants (dollar amounts) as measures of research productivity. In her salary study Bellas (1993) included a variable that measured time spent on research. Several studies, such as Ashraf (1996), Barbezat (1987), and Farber (1977), contained indicators of whether research was the primary work activity.

The literature generally acknowledges the shortcomings of available measures of scholarly production. Simple counts of articles and books published account for neither quality nor the importance of scholarship. Variables reflecting time spent on research are really measures of effort rather than production, and indicators of primary work activity likewise provide no information about faculty productivity.

Teaching Productivity

Controls for teaching productivity are less common in the literature than are controls for scholarship. Those studies that do control for teaching most often use measures of teaching load (hours spent in the classroom or number of courses).[17] In their salary study, Raymond et al. (1988) included grants (measured in dollars) awarded for instructional development. Both Barbezat (1989b) and Farber (1977) included indicators for teaching as a primary work activity.

The shortcomings of available measures of teaching productivity are apparent. Mostly, these measure effort or the focus of work activity, but they do not account for quality or results.

Personal Characteristics

Most of the salary studies we reviewed include some controls for personal characteristics. The most common of these are age, race/ethnicity, marital status, and family size (typically, the number of dependent children). Certainly, the last two characteristics, marital status and family size, are important controls for studies of male-female differences in earnings. As noted above, one hypothesis advanced in the literature is that family and parental responsibilities adversely affect women by making the accumulation of human capital more difficult and by leaving women with less time and energy to devote to their careers.

Findings

We summarize our findings from the literature as two sets of results: those from studies that used nationwide samples, and those from studies that used data from single academic institutions.

Nationwide Samples

Almost all of the studies that used nationwide samples show that women faculty earn less than male faculty do, even after controlling for other factors that might affect salaries. However, the estimated gender gap in earnings after the late 1970s appears to be smaller than the gap that existed in the 1960s and early 1970s.

[15] See our discussion of the Barbezat (1992) study in "Selection Issues," above.

[16] Johnson and Stafford (1974) make this argument.

[17] See, for example, Ashraf (1996), Winkler et al. (1996), Bellas (1993), and Barbezat (1989b).

Also, the estimated size of the gender gap appears to be somewhat sensitive to the kinds of controls used in different studies.

Earnings Differentials Over Time

Table 3-1 summarizes the results of salary studies using nationwide samples. We include in Table 3-1 only those studies that control at least for experience and academic field. This prevents inappropriate comparisons of unequals with respect to professional experience and comparisons across fields where different market conditions exist.

The first column in Table 3-1 identifies for each study the years in which salaries were observed. The second column shows the percentage female differential in earn-

Table 3-1. **Estimates of gender differences in earnings in nationwide samples**

Year[1]	Female differential (Percent)	Rank included	Publications included	Marital status or children included	Source
1965	–12.1	No	Yes	No	Ferber and Kordick (1978)
1966	–16.1	No	No	No	Tolles and Melichar (1968)
1968–1969	–20.7	No	No	No	Barbezat (1987)
1968–1969	–15.9	No	No	No	Ransom and Megdal (1993)
1968–1969	–16.5	No	Yes	No	Barbezat (1987)
1968–1969	–12.9	No	Yes	No	Ransom and Megdal (1993)
1969	–12.0	Yes	Yes	Yes	Ashraf (1996)
1970	–13.6	No	No	No	Johnson and Stafford (1974)
1972	–9.0	Yes	Yes	Yes	Ashraf (1996)
1972	–12.0	No	No	Yes	Haberfeld and Shenhav (1990)
1972–1973	–13.9	No	No	No	Ransom and Megdal (1993)
1972–1973	–11.3	No	Yes	No	Ransom and Megdal (1993)
1974	–12.0	No	Yes	No	Ferber and Kordick (1978)[4]
1974	–10.5	No	Yes	No	Ferber and Kordick (1978)[5]
1975	–10.4	No	Yes	No	Barbezat (1987)
1975	–12.7	No	No	No	Barbezat (1987)
1977	–6.4	Yes	Yes	No	Barbezat (1989a)
1977	–8.0	No	No	No	Barbezat (1987)
1977	–4.6	No	Yes	No	Barbezat (1987)
1977	–9.9	No	No	No	Ransom and Megdal (1993)
1977	–6.8	No	Yes	No	Ransom and Megdal (1993)
1977	–6.0	Yes	Yes	Yes	Ashraf (1996)
1982	–14.0	No	No	Yes	Haberfeld and Shenhav (1990)
1984	–6.6	Yes	Yes	Yes	Bellas (1993)
1984	–9.0	No	No	No	Ransom and Megdal (1993)
1984	–7.7	No	Yes	No	Ransom and Megdal (1993)
1984	–9.0	No	No	No	Barbezat (1989b)
1984	–6.8	No	Yes	No	Barbezat (1989b)
1984	—[2]	Yes	Yes	Yes	Ashraf (1996)
1987–1988	—[2]	(new hires)	No	No	Formby et al. (1993)
1988	–8.3	Yes	Yes	No	Broder (1993)
1989	—[2]	Yes	Yes	Yes	Ashraf (1996)
1993	–3.0	No	No	Yes	NSF (1996)[3]

[1]Indicates years covered by data used in study.

[2]Female differential not statistically significant.

[3]Sample includes doctorate earners employed outside of academia.

[4]Model estimated from sample of individuals earning doctorates between 1958 and 1963.

[5]Model estimated from sample of individuals earning doctorates between 1967 and 1971.

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ings after accounting for the effects of control variables. For example, the estimated differential in 1965 reported for the Ferber and Kordick (1978) study is –12.1 percent. This means that Ferber and Kordick estimated that, other things being the same, women faculty earned 12.1 percent less than male faculty in that year.

The estimated salary differentials in Table 3-1 show a relatively clear pattern over time. Studies that examined academic salaries in 1975 or earlier, with the exception of 1972 (Ashraf 1996), show double-digit percentage differences between men's and women's salaries. Barbezat (1987) estimated female-earnings differentials in 1968–1969 of 16.5 percent and 21 percent, depending on controls. However, after 1975 only the study by Haberfeld and Shenhav (1990) shows a higher than single-digit percentage differential.

The Equal Pay Act of 1963 and Title VII of the Civil Rights Act of 1964 both provide protection to women against discriminatory employment practices. Faculty at colleges and universities were initially exempt from the legislation, but in 1972 several executive orders and legislative acts made discriminatory treatment of women illegal in the academic labor market (Ransom and Megdal 1993). One explanation for the observed decline in estimated salary differentials is that colleges and universities implemented reforms in the affirmative action era that improved the relative earnings of women faculty by the late 1970s.[18] After 1977, however, female-earnings differentials appear to have flattened out.

Three studies of salary differentials in the 1980s show no significant differences between men and women in earnings. However, the results for two of these years, 1984 and 1989, are based on the Ashraf (1996) study, and Ashraf included academic rank as a control variable in his study. Discrimination in promotions will tend to mask male-female salary differentials. The insignificant result for the years 1987–1988 is based on the Formby et al. (1993) study; however, Formby et al. restricted their sample to new hires and studied salaries for only the academic field of economics.

The Effects of Control Variables on Earnings Differentials

Table 3-1 indicates whether three important kinds of variables—academic rank, publications, and marital status or the number of children—are included as controls in the studies listed. Including rank in faculty salary studies is controversial because discriminatory treatment in promotions tends to mask male-female salary differentials. The issue of scholarly production (e.g., the number of publications) is also important because most of the available evidence suggests that women publish less frequently than men do.[19] As a result, excluding scholarly production as a control is likely to increase measured salary differentials. Finally, we might hypothesize that family responsibilities negatively affect the career advancement, and hence earnings, of women faculty. In short, we would expect that including all three kinds of controls would reduce measured salary differentials.

Finding empirical evidence for these effects from the literature as a whole is complicated by the fact that different studies control for different combinations of factors, and because the gender gap appears to be changing over time. For the pre-1976 period, studies that excluded controls for rank, publications, and family characteristics tended to measure the largest salary gaps. For example, Barbezat (1987) measured the largest gap, 20.7 percent in 1968–1969, when she controlled for none of these factors, but when she controlled for publications, her estimate of the earnings gap for the same time period fell to 16.5 percent. Ashraf (1996), who controlled for all three factors, estimated the smallest pre-1976 earnings gap, 9 percent in 1972. A similar pattern appears in the post-1976 period. When controls for these three factors were excluded, Ransom and Megdal (1993) showed the largest post-1976 salary gaps, 9.9 percent in 1977 and 9.0 percent in 1984. Barbezat (1989b) also measured a 9.0 percent gap when these controls were excluded.[20] In contrast, Ashraf (1996), who controlled for all three factors, found no statistically significant salary gaps in his analyses of post-1977 data.

Some studies have focused on the issue of family responsibilities, but the evidence appears to be mixed. Johnson and Stafford (1974) attempted to address this issue indirectly by measuring returns received from work experience for men and women faculty members. They found that compared to men, women receive lower returns from experience (i.e., women's earnings are affected less by extra years of experience than are men's earnings) during typical child-rearing years. They interpreted this result as being consistent with the notion that be-

[18] See O'Neill and Sicherman (1997), Ransom and Megdal (1993), and Barbezat (1989b) for similar interpretations.

[19] See Section 5 of this review.

[20] Note that when Barbezat controlled for publications, the gender gap fell to 6.8 percent.

cause of job interruptions, women tend to accumulate less human capital than men do.[21] Similarly, Farber (1977) found that percentage increases in earnings for women faculty are lower than those for men only during childbearing years. However, Strober and Quester (1977) criticized Stafford and Johnson's interpretation of results, noting that the data they used do not include workforce interruptions. And Barbezat (1987) found that marital and parental variables do not have the predicted effect on female salaries.

Some of the indirect evidence on the effects of marital and parental variables is also mixed. If family responsibilities cause workforce interruptions, marital and parental variables might explain higher female exit rates from the science and engineering professions. Preston (1994) found that marital and parental variables positively affect female exit rates but not enough to explain the gender differential.[22]

Institutional Samples

Table 3-2 summarizes estimates of earnings differentials derived from studies of single academic institutions. All but two of these studies found negative salary differentials for women. Koch and Chizmar (1976) found that women earned about one percent more than men in 1973 at one institution. Raymond et al. (1988) found no significant difference in salaries earned by men and women faculty at another institution in 1984. Both studies controlled for academic rank.

The studies listed in Table 3-2 are arranged chronologically, but we caution against drawing inferences about trends in the gender gap over time. Variations in conditions across different institutions are likely to be large enough to distort changes that could be occurring over time. Megdal and Ransom (1985) studied data from the same institution at three points in time. They found negative salary differentials for women of 10.5, 6.3, and 9.5 percent in 1972, 1977, and 1982, respectively.

We have also indicated in Table 3-2 whether the various studies controlled for academic rank, publications, or marital and parental variables. Again, however, we caution against drawing conclusions about how these control variables affect estimated earnings differentials, because of likely variations in conditions across institutions.

Table 3-2. **Estimates of gender differences in earnings in single-institution samples**

Year[1]	Female differential (Percent)	Rank included	Publications included	Marital status or children	Source
1969	-15.0	No	Yes	No	Katz (1973)
1970	-9.0 to -11.0	Yes	No	No	Gordon et al. (1974)
1972	-10.5	No	No	No	Megdal and Ransom (1985)
1972	-4.0	Yes	No	No	Koch and Chizmar (1976)
1973	+1.0	Yes	No	No	Koch and Chizmar (1976)
1974	-10.0	No	Yes	No	Ferber et al. (1978)
1974	-16.0	No	No	No	Hoffman (1976)
1975	-2.0	Yes	No	No	Brittingham et al. (1979)
1977	-6.3	No	No	No	Megdal and Ransom (1985)
1977	-2.0	Yes	Yes	No	Martin and Williams (1979)
1980	-3.0 to -5.0	Yes	No	No	Hirsch and Leppel (1982)
1984	—[2]	Yes	Yes	No	Raymond et al. (1988)
1982	-9.5	No	No	No	Megdal and Ransom (1985)
1985	-5.0	Yes	Yes	No	Lindley et al. (1992)
1987	-6.0	Yes	No	No	Becker and Goodman (1991)

[1]Indicates years covered by data used in study.

[2]Female differential not statistically significant.

[21]Johnson and Stafford also found that the salary gap tends to narrow after age 45, when women reenter the workforce and begin accumulating more human capital.

[22]Preston's sample is not limited to scientists and engineers employed in academia.

Section 4. Academic Rank

There is substantial evidence that women, as a group, are underrepresented in senior academic ranks. The modeling issues discussed below should be considered when interpreting the results of empirical research on advancement to senior academic ranks.

Modeling Issues

Many of the studies on academic rank that we reviewed attempted to determine the effects of gender on academic rank after controlling for the effects of other factors that might affect promotions (e.g., experience and scholarly production). In most cases, these studies employed one of two kinds of analyses: discrete outcome models or hazard models.

Discrete outcome models permit multivariate analyses of outcomes that are observed as discrete events. This kind of model is appropriate for analyses of discrete career outcomes, such as academic rank or tenure (e.g., the individual is either tenured or not tenured). Two kinds of commonly used discrete outcome models are logit analysis and probit analysis.[23] Long (2001), Olson (1999), and Raymond et al. (1993) all used logit analysis in their studies of academic rank. Ransom and Megdal (1993), McDowell and Smith (1992), and Farber (1977) used probit analysis. Logit and probit analyses allow researchers to estimate, for example, the effect that gender has on the probability of being promoted to the rank of full professor after controlling for other factors that might affect rank, such as experience or scholarly productivity.

Hazard analysis is a useful tool for analyzing factors that affect the length of time required to achieve a given academic rank.[24] Both Weiss and Lillard (1982) and Kahn (1993) used hazard analysis in their studies of academic rank. Hazard analysis allows the researcher to estimate, for example, the effect that gender has on the time required to reach the rank of full professor after controlling for other variables affecting promotions.

The kinds of control variables used in the literature on academic rank are similar to those used in salary studies and include measures of human capital, measures of productivity, personal characteristics, and academic field.

Human Capital Variables

The rationale for including human capital variables as controls in studies of academic rank (and tenure status) is similar to the rationale for their inclusion in salary studies. Other things being the same, one would expect that individuals who have accumulated more human capital are more likely to receive tenure and to be promoted to senior ranks.

Experience

The number of years elapsed since earning the doctorate is perhaps the most commonly used measure of experience in academic rank studies. McDowell and Smith (1992), however, included a variable measuring years of academic experience in their study. Several authors, including Ransom and Megdal (1993) and Raymond et al. (1993), included years of service at the employing university as an institution-specific measure of experience.

Education

Some studies of academic rank include measures of educational quality as controls. For example, Long (2001) controlled for the prestige of the doctorate-granting institution in his study of tenure and promotions. Olson (1999) included as controls post-doctoral appointments and the Carnegie classification and departmental rankings of the doctorate-granting institution. Broder (1993) also controlled for the quality of the department from which individuals earned doctorates. When data included faculty who had not earned doctorates, some studies included control variables for the highest degree earned.

Characteristics of Employing Institution

Several studies, including Long (2001), Olson (1999), Broder (1993), Kahn (1993), and McDowell and Smith (1992) controlled for the characteristics of the employing institution. These controls could be interpreted as measures of human capital, given that individuals who have accumulated the most human capital are most likely to be employed at the most prestigious universities. In studies of academic rank, however, employer characteristics are probably better interpreted as proxies for variations in tenure and promotion requirements. Because promotion requirements are likely to be most

[23] Logit and probit analyses are similar statistical tools but differ in assumptions about the distributions of random modeling error.

[24] Hazard analysis, sometimes referred to as duration analysis, is superior to ordinary least squares regression analysis in that it can deal with censured observations. Observations on the length of time between promotions are censored in that individuals who have not yet been promoted are still observed in lower ranks.

stringent at the most prestigious institutions, institutional quality is likely to be negatively related to the probability of being promoted.

Measures of Productivity

Many of the studies of academic rank we reviewed controlled for scholarly productivity, but few controlled for teaching output and those that did used relatively simple controls. Only one of the studies reviewed included any controls for service to the academic community.

Scholarly Productivity

As in the salary studies, most of the academic-rank studies we reviewed used simple counts of the number of articles published as measures of scholarship. Olson (1999) controlled for the number of papers presented at conferences as well as the number of publications. Raymond et al. (1993) included research grant money awarded. Studies by Olson (1999) and Farber (1977) included indicators that research was the primary work activity as controls.

Teaching

As noted above, controls for teaching output are relatively rare and are simple in the academic-rank studies we reviewed. Two studies, Olson (1999) and Farber (1977), controlled for teaching as a primary work activity.

Personal Characteristics

Generally, fewer academic-rank studies than salary studies controlled for personal characteristics. A few studies controlled for such factors as age, age at the time of earning the doctorate, and race/ethnicity. Unfortunately, only three studies, Long (2001), Olson (1999), and Winkler et al. (1996), included marital and parental variables.

Findings

Table 4-1 summarizes the findings of multivariate studies of the effects of gender on academic rank. Each of the studies listed in this table controls for at least some measure of experience and academic field.[25] The first column in Table 4-1 identifies the years covered by each study. The second column briefly summarizes the findings of each study.[26]

Taken as a whole, the findings from the literature suggest that, other things being the same, female faculty find it more difficult than male faculty to achieve tenure and to be promoted to senior academic ranks. Of the studies that we have reviewed, only two found no statistically significant gender differences in promotion rates. Raymond et al. (1993) found no evidence of gender having an effect on academic rank, but this study used data for a single institution. A study by McDowell and Smith (1992), who used data for only the field of economics, found no statistical difference in promotion rates between men and women after allowing for gender differences in the effect of experience on academic rank. They did find that women receive less credit for experience than men do. Interpreting gender differences in returns received from experience has raised controversy in the literature. Gender differences in credit for experience could be due either to gender differences in human capital accumulation (caused by family responsibilities and workforce interruptions) or to gender bias.

The findings from some of the studies we reviewed suggest that women faculty are placed at a particular disadvantage by family responsibilities during child-rearing years. For example, Farber (1977) found that women receive significantly fewer promotions when they are young but found no significant differences in promotion rates for older women. McDowell and Smith (1992) concluded that promotion rates for women are lower than those for men because women receive less credit for years of experience. Gender differences in family responsibilities may be responsible for this finding.

Kahn (1993) found that women are less likely than men to receive tenure but found no gender effect for the time between promotion from associate to full professor. The tenure decision, which usually coincides with promotion from assistant to associate professor, often occurs during early child-rearing years.

Long (2001) and Olson (1999) estimated separate promotion models for women and men and included con-

[25] We adopted two criteria for including in Table 4-1 studies that we reviewed. First, the studies must include original empirical research on the relationship between gender and tenure or academic rank. Second, the studies must attempt to control for factors other than gender that might affect tenure and promotion.

[26] The results of the academic rank studies are more difficult to summarize quantitatively than are the salary studies. This is due in part to differences in modeling approaches across studies and the kinds of quantitative results reported by the authors.

trol variables reflecting the number of children at home. Olson found that having children significantly reduces the chances of promotions for women but not for men. Long's results do not show consistent, statistically significant gender differences in relations between promotion rates and having children.[27]

Table 4-1. **Estimates of gender differences in rank and tenure**

Year[1]	Findings	Fields included	Modeling technique	Source
1960–1966	Compared with men, women receive fewer promotions when under age 40; promotions comparable at ages 40–50	Several S&E fields	Probit analysis	Farber (1977)
1960–1970	Women wait twice as long as men to be promoted	Several S&E fields	Hazard analysis	Weiss and Lillard (1982)
1969–1984	Women less likely than men to be in senior ranks; promotion rates of women about the same as for men with 1–2 years less experience	All academic fields	Probit analysis	Ransom and Megdal (1993)
1969–1986	Women's experience counts less for promotions than men's	Economics	Probit analysis	McDowell and Smith (1992)
1973, 1983	Women less represented at full professor level (20% to 59%)	Chemistry	Descriptive statistics	Everett et al. (1996)
1979, 1989, 1995	Women less likely to be full professor, tenured, or on tenure track	All S&E fields	Logit analysis	Long (2001)
1983–1987	Gender does not affect likelihood of promotion	All academic fields	Logit analysis	Raymond et al. (1993)[2]
1988–1989	Women with more than 6 years of postdoctoral experience more likely than men to be in lower ranks	Economics	Logit analysis	Broder (1993)
1989	Women less likely to be tenured; no gender effect for time between tenure and full professor rank	All S&E fields	Hazard analysis	Kahn (1993)
1989	Women make up 51% of instructors, 38% of assistant professors, 28% of associate professors, and 13% of full professors; also less likely to be tenured or on a tenure track	Several academic fields	Descriptive statistics	Carnegie Foundation (1990)
1990	Women disadvantaged with respect to rank and tenure	Several S&E fields	Regression analysis	Sonnert and Holton (1995)
1992	Small number of women associate professors	Atmospheric sciences	Descriptive statistics	Winkler et al. (1996)
1993	About 21% of women employed at full professor compared with 62% of men	Chemistry	Descriptive statistics	Everett et al. (1996)
1995	Women less likely to be full professor, in senior ranks,[3] tenured, or on tenure track	All S&E fields	Logit analysis	Olson (1999)
1997	Women more likely to be employed as instructors and assistant professors	Geosciences	Descriptive statistics	Ongley et al. (1998)

[1]Indicates years covered by data used in study.

[2]Study conducted for a single academic institution.

[3]Senior ranks include associate- and full-professor ranks.

KEY: S&E = science and engineering

[27]Neither Long nor Olson standardized the timing of when children are observed during the postdoctoral career. The timing of fertility might affect the influence that children have on academic careers (e.g., having children before or after the tenure decision).

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Section 5. Scholarly Productivity

In our review, studies that modeled scholarly productivity directly as an outcome found that, other things being the same, women faculty tend to publish less frequently than their male counterparts. Some of these differences might be explained by job selection and gender sorting by coauthors, as men and women tend to collaborate with coauthors of the same sex. With relatively few women faculty, it is more difficult for women to find collaborators.

Evidence on Publications by Gender

Several studies in our review modeled scholarly productivity as outcomes using national data, a broad range of academic fields, and controls for experience and a number of other factors that might affect publication rates. These studies found lower scholarly output among women faculty relative to their male counterparts.

Hamovitch and Morgenstern (1977) used data from the Carnegie Council of Education to look at gender differences in the number of articles published.[28] They controlled for several factors, including experience (years since earning the doctorate), hours spent teaching, and number of children in the family, and found that women publish about 20 percent fewer articles than do men. They found no statistically significant relationship between publications and the number of children in the family.[29]

Mathtech (1999) used data from the 1991, 1993, and 1995 waves of the Survey of Doctorate Recipients to study articles published and papers presented by scientists and engineers.[30] After controlling for a variety of factors, including experience, academic field, kind of graduate support, marital status, number of children, and other personal characteristics, Mathtech found that women present about 1.2 fewer papers and publish about 1.4 fewer articles than do men.

Sonnert and Holton (1995) used a survey of former National Science Foundation and National Research Council postdoctoral fellowship recipients to measure gender differences in scholarly productivity. They found that women in their sample had about 0.5 fewer publications than men did, a statistically significant difference even after controlling for fields.

Two studies focused on publication rates in the field of economics. Although the degree to which these results can be generalized to other fields is open to debate, these studies do shed light on differences in scholarly output between men and women faculty.

Broder (1993) measured scholarship as the number of articles published in top economics journals. After controlling for experience, quality of the graduate school attended, and quality of the employing institution, she found that female academic economists publish about 1.9 fewer articles in top journals than their male counterparts.

Koplin and Singell (1996) controlled for similar variables in their study, including quality of graduate education and current employer, but used a quality-weighted index of scholarly productivity instead of a simple count of articles published. The quality index was computed as the number of citations the journal received per article published times 1000. Koplin and Singell defined scholarly output as the sum of quality-weighted articles published. They found that, other things being the same, women's scholarly output is significantly higher than men's.

Both the Broder and the Koplin and Singell studies are significant in that they controlled for the current employment situation of individuals in their analyses. Women tend to take jobs in less-prestigious institutions and jobs that stress teaching over research (see Section 2). Thus, Broder's results imply that women tend to publish less than the men at comparable institutions do. Koplin and Singell, however, found that after adjusting for the quality of scholarship, women tend to be more productive than men at comparable institutions are.[31]

[28] Hamovitch and Morgenstern restricted their sample to full-time workers and criticized prior research for including part-timers.

[29] This finding is consistent with results reported by Cole and Zuckerman (1991), who found no difference in publication rates for single and married women.

[30] The Mathtech sample was restricted to doctorate recipients with eight or fewer years of experience and included individuals working outside of academia.

[31] Koplin and Singell noted that the raw-publication counts in their data indicate that women publish less than men do and that their results depended on the quality index they used.

Gender Sorting by Coauthors

We reviewed two studies that focused on gender sorting by coauthors. Both found that men and women faculty tend to publish with coauthors of the same sex. Because both studies limited their samples to economists, generalization to other fields should be done cautiously. However, the findings of these studies are significant in that they suggest that coauthoring places women at a disadvantage in publishing.

McDowell and Smith (1992) found a statistically significant propensity on the part of both male and female economists to coauthor. They also conducted a multivariate analysis of the decision to coauthor and found that women are less likely than men to coauthor. This finding, they argued, is likely the result of women finding it difficult to coauthor because of the relatively small proportion of women in the profession.[32] McDowell and Smith concluded that the difficulty in finding coauthors poses a particular disadvantage for women, because their subsequent analysis showed that academic institutions tend to give single-authored and coauthored publications equal weight in promotion decisions.

Like McDowell and Smith, Ferber and Teinman (1980) used a sample of economic journal articles to show a statistically significant tendency for coauthors to collaborate with the same sex. Ferber and Teinman also analyzed journal acceptance rates from a survey sponsored by the Committee on the Status of Women in the Economics Profession. They found that when referees are blind to sex, articles submitted by women (either alone or with a male coauthor) have a significantly higher acceptance rate than articles submitted by men. However, when sex is known (or can be inferred from names), they found no statistically significant difference in acceptance rates.

[32]McDowell and Smith speculated that the coauthorship problem might cause women to seek jobs in larger departments with more women in an effort to find research partners.

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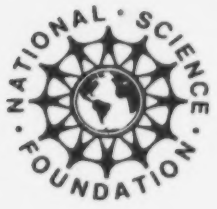

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